Cold Regions Science and Technology 133 (2017) 1–6

Contents lists available at ScienceDirect

Cold Regions Science and Technology

journal homepage: www.elsevier.com/locate/coldregions

Influence of mineral filler on the low-temperature cohesive strength of asphalt mortar

Zheng Chuanfeng [a,b,*], Feng Yupeng [a], Ma Zhuang [a], Yang Xue [a]

[a] College of Construction Engineering, Jilin University, Changchun 130026, China
[b] College of Traffic, Jilin University, Changchun 130021, China

ARTICLE INFO

Article history:
Received 18 September 2015
Received in revised form 15 August 2016
Accepted 19 October 2016
Available online 22 October 2016

Keywords:
Asphalt mortar
Cohesive strength
Content of mineral filler
Matrix strength
Agglomeration
Effect mechanism

ABSTRACT

The effects and influence mechanisms of different filler-to-bitumen ratios on the low-temperature cohesive strength of asphalt mortar were studied using quantitative testing technology. Two control variables, namely filler-to-bitumen ratio (the quality of the mineral filler/quality of asphalt) and temperature, were selected for this experiment. The first variable was divided into six groups. The cohesive strength of each group was then measured under different low-temperature conditions. Results show that the optimization of filler-to-bitumen ratio was related to the cohesive strength of the asphalt matrix, which was in turn associated with the change on the surface between the asphalt matrix and the strength of the mineral power fillers generated from asphalt embrittlement. Therefore, the optimal filler-to-bitumen ratio should be determined by the local low-temperature conditions. Moreover, the cohesive strength of the asphalt matrix, its embrittlement state and the contact surface strength effect of asphalt filler should be comprehensively considered in determining the optimal filler-to-bitumen ratio.

1. Introduction

Studies have shown that the mechanical strength of asphalt mortar has a significant impact on the low-temperature performance of asphalt mixtures (Riccardi et al., 2016; Wu et al., 2015). The low-temperature cohesive strength is an essential mechanical parameter that reflects the resistance capacity of asphalt mortar to various loads (tensile loads or shear loads). Thus, the low-temperature cohesive strength of asphalt mortar is closely related with the performance of the asphalt mixture at low-temperature pavements. It has attracted widespread attention of researchers in the recent years (Pirmohammad et al., 2016; Anyi et al., 2015; Wang et al., 2014).

As an important component of asphalt mortar, mineral powder filler accounts for a relatively large proportion in asphalt mortar; thus, it is an essential factor in the mechanical performance of asphalt mortar (Nassar Ahmed et al., 2016; Cheng et al., 2016). Determining the appropriate content of mineral powder filler is the prerequisite for its optimal application. The use of strength parameters of asphalt mortar as control indices is more feasible for determining the optimal content of mineral powder fillers because asphalt mixture testing is highly discrete (Mwanza Aaron et al., 2012; Menglan & Wu, 2008).

Low-temperature cohesive strength is a significant mechanical parameter of asphalt mortar, so in this paper we analysed the effects of mineral powder fillers to the low-temperature cohesive strength of asphalt mortar. Cohesive strength can determine the optimal content of mineral powder fillers under different temperature conditions.

2. Experimental materials

SBS-modified asphalt (SBS is the abbreviation of styrene–butadiene–styrene triblock copolymer) which prepared by mixing the 90# matrix asphalt with 4% SBS modifier, was chosen as the experimental material. Prior to the experiment, the basic performance parameters were all tested, such as penetration (at 5 °C and 25 °C), ductility, softening point and standard viscosity (at 60 °C and 90 °C). The results of the basic performance parameters are shown in Table 1. Limestone power, which is widely used in China currently, is selected as the mineral filler. Prior to the experiment, it needed to be screened by a standard sieve to ensure its macro-gradation and to meet the relevant standard requirements. Mesoscopic gradation was conducted with a BT-1600 particle image analysis system. The test results are presented in Fig. 1.

3. Experiment method

3.1. Preparation of asphalt mortar

In this research, the filler-to-bitumen ratio was fully refined to analyse the effects of the cohesive strength of asphalt mortar under low-temperature conditions. These ratios were designated as 0:1, 0.6:1,

* Corresponding author.
E-mail addresses: cfzheng0527@hotmail.com (Z. Chuanfeng), fengyp13@mails.jlu.edu.cn (F. Yupeng), mazhuang14@mails.jlu.edu.cn (M. Zhuang), yangx14@mails.jlu.edu.cn (Y. Xue).

http://dx.doi.org/10.1016/j.coldregions.2016.10.006
0165-232X/

Table 1
Technical parameters of SBS-modified asphalt.

Asphalt species	Penetration/0.1 mm		15 °C ductility/cm	Softening point/°C	Standard viscosity/pas	
	5 °C	25 °C			60 °C	90 °C
SBS-modified asphalt	7.5	97.2	>100	44.7	6246	3820

0.8:1, 1:1, 1.2:1, 1.5:1 and 2:1. To eliminate the influences of the microscopic characteristics of mineral powder, the BT-1600 particle image analysis system was used to test the mesoscopic characteristics of all of the mineral powder fillers before they were mixed. During the experiment, the hot asphalt mortar was cut completely with a high-speed shearing machine after the mineral fillers were added to ensure that the mineral fillers and the bitumen matrix were fully combined. The six groups of asphalt mortars with different filler ratios were thus produced (Fig. 2).

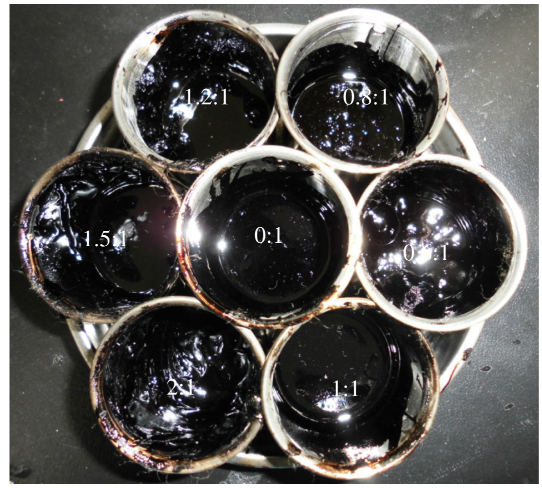

Fig. 2. Asphalt mortar with different filler ratios.

3.2. Quantitative testing technology of the low-temperature cohesive strength

The author and the author's research team developed a quantitative testing technology for the low-temperature cohesive and adhesive strengths of asphalt mixtures during the period of 2012 to 2013 to conduct pavement performance research on asphalt mortar in low-temperature conditions and to analyse the change rules of the low-temperature performance of asphalt generated by mixing the contents of different mineral power fillers, the mesoscopic characteristics of mineral power fillers and the proportion of asphalt components based on the refinement test method. This technology can also be used to conduct relevant research, and it has been authorized as a patented Chinese invention (Patent No. CN 102830062 B) (Zheng et al., 2014; Zheng et al., 2013).

This type of test technology was used to measure the low-temperature cohesive strength of asphalt mortar based on tensile load damage. The testing principle is illustrated in Fig. 3. When the oil film on the asphalt was relatively thick (approximately 0.45 mm), this film was damaged only through the failure of the cohesive strength of the asphalt binder, as per extensive exploration experiments. Besides, the adhesive capability of the contact surface of the asphalt mineral aggregate did not fail under low-temperature conditions. Thus, the thickness of the asphalt mortar oil film was set as 0.5 mm prior to testing to prevent the adhesive failure effect during the experiment. This condition ensured that the asphalt mortar oil film failed only as a result of the cohesive weakness of the asphalt mortar. Moreover, the low-temperature cohesive strength of asphalt mortar was easy computed according to the tensile failure load and the failure area of the oil film under the corresponding low-temperature conditions (see Eq. (1)). The equipment used in the test is shown in Fig. 4, the test mold of the mineral aggregate was made by the alkaline limestone. A rectangular frame of steel wire with 0.5 mm diameter was set on the surface of the test mode during the experiment to control oil film thickness, the asphalt mortar evenly titrated on test mode surface by titration way, then the small scraper will be used to make the oil film smooth.

$$R_c \times S = F \tag{1}$$

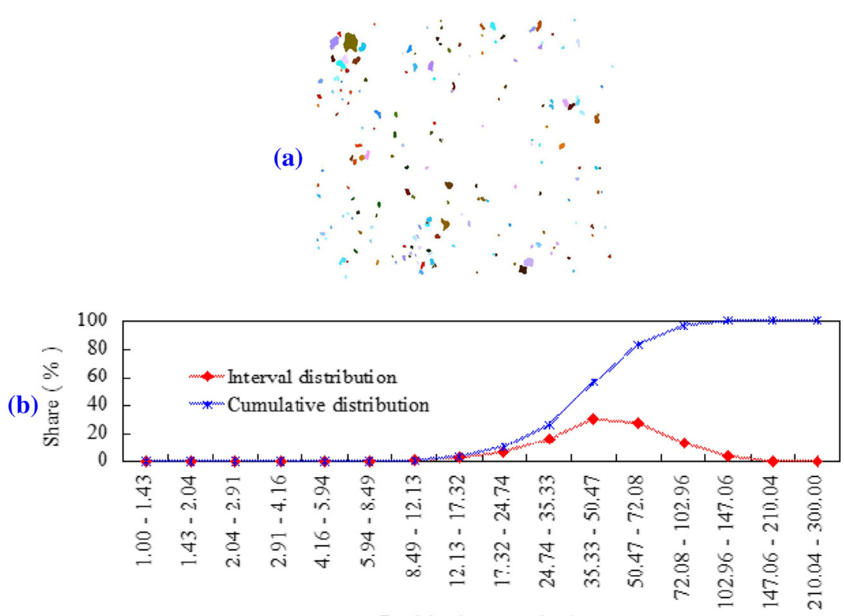

Fig. 1. Mesoscopic gradation of mineral power fillers (a. mesoscopic image of mineral power fillers; b. cumulative distribution of the particle sizes of mineral powder fillers).